

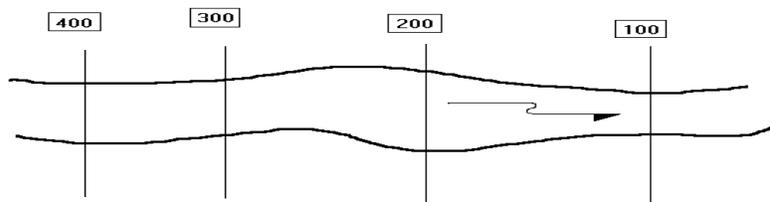


STATE OF CONNECTICUT  
DEPARTMENT OF ENVIRONMENTAL PROTECTION  
BUREAU OF WATER MANAGEMENT  
INLAND WATER RESOURCES DIVISION

# Hydraulic Analysis Guidance Document

## Supplemental Guidelines for Preparing Riverine Hydraulic Analyses in Permit Applications Submitted to the Inland Water Resources Division Including:

- Inland Wetlands and Watercourses Permits
- Stream Channel Encroachment Line Permits
- 401 Water Quality Certifications
- Water Diversion Permits
- Dam Construction Permits
- Flood Management Certification Approvals



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# Hydraulic Analysis Guidance Document

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## **Section 1. Introduction**

### ***Purpose of Guidelines***

These guidelines have been prepared by the Inland Water Resources Division (IWRD) to assist engineers in the preparation of engineering reports where hydraulic modeling is required. Such engineering reports are required to be submitted with IWRD permit applications for projects that fall within the IWRD's jurisdiction. Specifically, these guidelines detail the documentation necessary to demonstrate that a project is in compliance with the requirements of the State of Connecticut Flood Management Statutes and Regulations (Sections 25-68b through 25-68h of the Connecticut General Statutes [CGS] and Sections 25-68h-1 through 25-68h-3 of the Regulations of Connecticut State Agencies [RCSA]) applicable statutes and regulations. It also details the preferred format in which the documentation should be submitted to the Department of Environmental Protection (DEP). It does not include the modeling requirements for open channel modifications, storm drainage systems, or stormwater detention facilities. Further information on these specific types of projects may be found in RCSA Section 25-68h-3.

### ***Note to Users***

These guidelines are intended for persons with a background in hydraulic modeling, therefore it is assumed that technical terms are generally understood and do not need to be explained. Applicants should remember that these guidelines have been prepared to outline a suggested format for documenting and presenting your modeling work and are not intended to provide training in the design of bridges, roadways, commercial site development, or wetlands mitigation. Compliance with these guidelines does not create a presumption that your project will be approved. Applicants should review all applicable statutes and regulations prior to preparing an application, including, where applicable, the provisions of the coastal management statutes, Chapter 444 of the general statutes.

### ***When is a Hydraulic Analysis Required?***

In any case where changes are proposed in a floodplain or in a watercourse which may affect the conveyance of flood flows, hydraulic information as outlined in this report is required. This includes but is not limited to; bridge/culvert replacements or relocations of any kind, bridge superstructure replacement if the hydraulic opening of the bridge is changed in any way, channel modifications including the placement of bank stabilization material, fill placed in a floodplain, excavation in a floodplain, or any combination of fill and excavation. The complexity of the analysis depends on whether special circumstances exist, such as the presence of a Federal Emergency Management Agency (FEMA) floodway or stream channel encroachment lines (SCEL) at the site.

## **Section 2. Governing Policies**

The following statutes and regulations establish the Flood Management policies and practices of the DEP:

- State of Connecticut Flood Management Statutes and Regulations (CGS Sections 25-68b through 25-68h and RCSA Sections 25-68h-1 through 25-68h-3). All applications for permits in the programs administered by the IWRD are reviewed to insure that the proposed activities are in conformance with applicable flood management standards and criteria.

- National Flood Insurance Program (NFIP) (44 CFR, Chapter 1, Subchapter B, Part 60.3). The NFIP standards and criteria are the basis for the minimum requirements of the State's Flood Management Program.
- Inland Wetlands and Watercourses (CGS Section 22a-39 through 22a-45a), Dam Construction (CGS Section 22a-401 through 22a-411), Water Diversion (CGS Section 22a-365 through 22a-379a), Water Quality Certifications under Section 401 of the Federal Clean Water Act (33 USC 1341), and Stream Channel Encroachment (CGS Sections 22a-342 through 22a-349). These programs regulate Connecticut's inland water resources. Applications for permits in these programs are evaluated for environmental and flooding impacts.
- CGS Section 13a-94 requires that all structures built over or adjacent to streams in connection with state highway projects conform to the Stream Channel Encroachment Program requirements.

Most communities in Connecticut have adopted Flood Insurance Rate Maps and Floodway maps in conjunction with the NFIP administered by the FEMA for use in regulating development within floodplains. Many streams and rivers in these communities have been studied for the purpose of defining a flood plain area and a floodway area. The floodway is the central part of the floodplain that is reserved to ensure that a sufficient part of the flood plain will remain open to carry flood waters efficiently.

The following are some of the standards and criteria which must be met in order for a project to be consistent with the State's Flood Management Policies:

- **Floodplains.** RCSA Section 25-68h-2(c)(1) prohibits any activity in a floodplain which would adversely affect the hydraulic characteristics of the floodplain. This includes floodplains in both inland areas and coastal areas. All permit applications for projects proposed within a floodplain must demonstrate that the project will not cause adverse impacts to upstream, downstream, or adjacent properties.
- **Floodways.** RCSA Section 25-68h-2(c)(5) and Section 60.3(d)(3) of NFIP regulations prohibit any activity within a regulatory floodway which would result in any increase in the base flood water surface elevation. In order for any proposed project which does not meet these standards to be approved, a map revision is required from FEMA.
- **10-Year Profiles.** RCSA Section 25-68h-2(c)(5) prohibits any activity within a regulatory floodway which would result in an increase in the elevation of the 10-year water surface profile.

- **Stream Channel Encroachment Lines.** The State of Connecticut has established Stream Channel Encroachment Lines (SCELS) on approximately 270 miles of flood prone rivers in the state. This program differs from the Flood Management Certification program in the scope of review and the extent of jurisdiction, as well as the base flood elevations and discharges for individual watercourses. Maps showing the regulated areas are on file with the IWRD and are also on file in the Town Clerk's offices in each town where lines have been established.

CGS Section 22a-342 requires that the DEP evaluate proposed encroachments based on the flood-carrying and water storage capacity of the waterways and floodplains, flood heights, hazards to life and property, and the protection and preservation of the natural resources and ecosystems of the state, including but not limited to ground and surface water, animal, plant, and aquatic life, nutrient exchange, and energy flow, with due consideration given to the results of similar encroachments constructed along the reach of waterway.

- **Natural Profile.** Bridges and culverts should be designed so that the proposed water surface profile does not exceed the natural profile by more than one foot for the 100-year or SCEL floodplain analysis. This applies to the replacement of existing bridges and culverts as well as the construction of new structures. If the proposed profile does not meet this standard, documentation must be submitted justifying the basis for the design. This standard does not apply to DOT Flood Management Certifications for projects which have a drainage area of less than one square mile. These projects have been exempted by regulation from Flood Management standards. Notwithstanding the above, any increase over the existing water surface elevations will only be permitted provided no adverse impacts are created.
- **Water Resources.** The project should not adversely affect the environment or long range water resource planning or impair proper management and use of the water resources of the State.
- **Fish Habitat.** The project must provide for adequate fish passage and maintenance of fish habitat in watercourses which may support fish. DEP Fisheries should be contacted in advance for technical advice for any project which may impact fisheries

### Section 3. Fundamentals in Modeling River Hydraulics

**Selection of Computer Modeling Programs.** Most hydraulic models used in support of permit applications are one-dimensional models for calculating water surface profiles which assume steady gradually varied flow. Programs such as HEC-2, HEC-RAS, WSP2 and WSPRO are all acceptable models, since these are models which are in the public domain and can be recreated for review. In general, no other models should be submitted to the IWRD. Other models may be acceptable, with prior approval from DEP, provided they use the standard step method of solving the Energy Equation:

$$\boxed{WS_2 + a_2 V_2^2 / 2g = WS_1 + a_1 V_1^2 / 2g + h_e}$$

Unique situations may require specialized modeling, such as two- or three- dimensional models. If you are not using one of the above listed models, you must consult with the IWRD before submitting your application. The models used by FEMA to map floodplains assume subcritical flow and applicants recreating a FEMA study should apply the same assumption. In almost all cases, the FEMA analysis is available only on hard copy which necessitates recreating the files for use on the computer. This should not be a problem unless the FIS utilized the U.S. Geological Survey's E431 or J635 computer programs. Neither of these programs can be run on a personal computer so it is necessary to convert the input data to another hydraulic model. In all other situations, the applicant should utilize the latest version of the same computer model as was used by FEMA, except that HEC-2 data may be run in the program HEC-RAS.

**Design Discharge.** If the subject site is located in a FEMA floodway or a *numbered "A"* zone, the discharge for analyzing the acceptability of a project at that site must be the same discharge used by FEMA in establishing the floodway or *numbered "A"* zone designation for the site. If the subject site is located in an *unnumbered "A"* zone or is not located in a FEMA flood zone, such that no detailed study is available), the applicant must establish an appropriate design discharge for evaluating the acceptability of the project at that site. If an applicant uses a design discharge other than the discharge used by FEMA, the applicant must still evaluate the project using the FEMA design discharge and provide a detailed justification as to why another discharge was selected. Both the applicant's selected design discharge and the FEMA discharge analyses must be submitted in the application package. If the subject site is riverward of SCCEL, an analysis using the SCCEL discharge must also be submitted. If the site is located in a floodway, the 10-year discharge must also be evaluated.

### ***Existing Conditions Model***

**FEMA Cross Section Data.** As a starting point for any hydraulic modeling of a river mapped by FEMA, the most recent cross sections published in the specific community's Flood Insurance Study should be used. Applicants should contact FEMA Region I - Mitigation Division at 617-223-9561 for information on how to obtain a copy of the FIS back-up data. Applicants should note that the average request takes approximately 2 to 4 weeks to fill and costs between \$100 and \$200.

**FEMA Calibration Run.** The back-up data obtained from FEMA must be run "as-is" to check for any differences which may appear simply because a different version of the same model is used, or in cases where a different model is used (as when the original is unavailable to the public). This run must be included in the application package along with a summary of any differences from the published information which may occur.

**Use of Cross Sections to Define a Site.** An *existing conditions model* and an *existing conditions encroached model* (if a floodway is present) should be developed by utilizing the FIS data and inserting additional cross sections where appropriate to define the project site. This is often necessary because the FIS section locations are frequently far apart and may not be located within the project limits. In the case where FEMA has accurately modeled an existing condition, the FEMA calibration run may be used for the existing conditions run unless additional cross sections are needed to define a proposed condition. For example, additional cross sections may be needed to define the site of a bridge relocation or widening. (Note: Each

cross section from the *proposed conditions model* must have a matching section in the *existing conditions model*.) Existing cross sections should be taken at the locations of the downstream and upstream right-of-way limits in order to define water surface elevations in the areas beyond the roadway right-of-way. Cross section locations should be consistent with the recommendations of the manual for the model utilized.

As a starting point, the inserted cross sections should utilize roughness, contraction and expansion coefficients identical to those used by FEMA. Subsequently, based on the professional judgement of the engineer, these coefficients may need to be adjusted to reflect actual field conditions or if there are difficulties in matching the FEMA model. Such adjustments should be noted and summarized. Cross sections must span the entire floodplain. These cross sections may be a combination of survey data and existing available topographic information where appropriate. If sources other than survey data are used, an explanation should be provided. The floodway limits at the inserted sections should be scaled from the FEMA floodway maps. Floodway limits may not be modified unless a map revision has been issued from FEMA.

**Accuracy of Available FEMA Cross Sections.** The FEMA cross sections within the study reach of the proposal should be compared to current survey information at the location of the FEMA cross sections in order to determine their accuracy. In situations where any discrepancies found between the FEMA data and the current survey information are relatively minor (generally matching to within 0.5' is acceptable), the FEMA data should be used to create the *existing conditions model*. The *existing conditions model* will be used for a comparison to the *proposed conditions model*. In cases where the discrepancies between the FEMA cross sections and the current survey information are unacceptable, or obvious input errors are noted, data from the actual site conditions should be utilized.

**Map Revisions.** Any request to amend or modify an existing floodway must first receive a letter or a conditional letter of map revision (LOMR or CLOMR) from FEMA before DEP will issue an approval. The purpose of a CLOMR is to ensure that the modifications will be acceptable to FEMA. A LOMR is not generally issued until a project is complete. The map revision process may be lengthy, so be sure to allow sufficient time for this process in your project schedule. The applicant should contact FEMA to obtain the most current document which outlines the procedures for obtaining a CLOMR.

**When There is no Detailed FEMA Study.** If FEMA has not established a flood zone with elevations on the watercourse or has not established a floodway, the applicant must develop an *existing conditions model* using field survey data and reasonable coefficients with a calculated design discharge based on a hydrologic model which is appropriate for the site such as TR-55. In some cases where a culvert is proposed to be replaced in an area which has an unnumbered "A" zone, use of a model such as HY-8 may be acceptable for use in calculating differences in the water surface elevation upstream of the proposed culvert.

**When FEMA Data is Unavailable.** In some situations the FEMA input information is not available. In this case, applicants must provide the DEP a letter from FEMA indicating that the requested material cannot be supplied. Applicants may then exclusively use field survey data to produce a model that matches as closely as possible to the published FIS model. A closer match may be made by adjusting roughness, contraction, and expansion coefficients. At minimum, cross sections should be taken as close to FEMA sections as possible. On rivers with established SCEL, cross section information from the SCEL study may be available from the DEP.

### ***Natural Conditions Model***

For new or replacement bridges and culverts, a *natural conditions model* must be developed. The natural conditions model is intended to show the floodplain in the vicinity of the project as it would be without any artificial encroachments or modifications. For replacement bridges the natural profile may be developed by modifying the *existing conditions model* to remove the bridge or culvert structure and any approach embankments. In the case where a downstream bridge or dam affects the tailwater of the bridge at the site, two models are required. The first model should show the natural conditions with all obstructions removed. The second model should show the proposed conditions with the downstream obstruction removed but the subject bridge left in place. This will more clearly demonstrate the effect of the subject bridge in comparison with natural conditions. The backwater value of the proposed bridge will be considered to be the difference between the two models.

### ***Proposed Conditions Model***

The *proposed conditions model* and *proposed conditions encroached model* (if floodway is present) is developed by modifying the *existing conditions model(s)* to reflect proposed changes. The *proposed conditions model* is compared to the *existing conditions model* to evaluate the hydraulic impacts of the project. The proposed project must not increase the water surface elevations for the 10 or 100 year floodway (encroached condition) profiles. If the proposed activity causes any increases, then the project design must be modified to eliminate these increases. If increases are shown for the unencroached 100 year profile or the SCEL profile, the impacts must be thoroughly discussed. Adverse impacts are not permissible. Additionally, for bridge and culvert projects, the proposed profile must be compared to the natural profile to determine if the design satisfies the goal of no more than one foot of backwater over the natural profile for the 100 year and/or the SCEL floodplain analysis. The applicant must satisfy this goal unless they can demonstrate unusual circumstances such as adverse property or environmental impacts.

When a floodway run is required, you must use FEMA's discharge. Do not propose increases in the floodway model over the model representing existing field conditions. Remember, proposed encroachments into the regulatory floodway will not be permitted if the project results in any increase (greater than **0.00** feet) in either the 10 or 100-year floodway (encroached condition) profiles. The IWRD will not approve an increase in the floodway elevations unless FEMA has granted a conditional letter of map revision. Some increase in the floodway elevations within the roadway right-of-way of a state project may be acceptable without FEMA's prior approval.

If the proposed unencroached 100-year water surface profile will be lower than the published information by more than 0.5 feet or if there are significant differences in the published data and the proposed water surface elevation due to modeling differences or errors in the FEMA data, you must notify FEMA by letter with a copy to the town and DEP once the project is complete and provide to FEMA the hydraulic model information with the 500 year, 100 year, 50 year and 10 year flood profiles and an equal conveyance floodway. The letter sent to FEMA should make it clear that the information is being submitted for FEMA's future mapping use and not for a current map revision, as per agreement between DEP and FEMA. The address for the FEMA Region I office (serving Connecticut) is:

J.W. McCormack Post Office and Court House  
Room 442  
Boston, MA 02109  
617-223-9561

#### **Section 4. Summary and Presentation of Information**

The results of the hydraulic modeling should be clearly summarized in the engineering report to show water surface elevations, velocities and cross section information. This is best done through tables, profiles, cross section plots, and a clear narrative. A well-organized presentation can greatly facilitate timely permit reviews.

Hydraulic analyses should be submitted with the input data and full output tables. In the engineering report, conclusionary statements should be explained and fully supported by back-up data. Copies of computer output sheets should be checked for legibility. Often these pages are too light to read after being copied.

A 3.25" computer diskette or CD (preferred) of all input files contained within the report with an index of these files should be included with the engineering report. Label the disk with the project name. By including this diskette, some additional information requests may be avoided. In addition, if a disk is included, the output of the models need not be submitted; only a hard copy of the input and the summary tables must be included in the submittal.

**Narrative.** A narrative sufficient to explain the project should accompany the hydraulic analyses. The narrative should contain sections for project description, natural conditions, existing conditions, proposed conditions, and the hydraulic summary. Unusual error messages identified by the hydraulic analysis should be explained and/or commented upon. A complete narrative will assist DEP staff to understand unusual circumstances or complex situations pertaining to the project. Any other information that the applicant feels will be helpful in assessing the project should also be included. Make sure the copies of the engineering report, especially computer printouts and hand computation sheets are legible. If the report is bound, make sure that no portions of the computer printouts are obscured. Reports should be tabbed and labeled so that sections can be easily located.

**Profiles.** In a report containing more than one discharge, profiles should show existing, proposed, and natural conditions on one page for each discharge. This enables an easy comparison of the profiles. A separate page should be used for each discharge. The existing and proposed profiles should converge both upstream and downstream of the project site or at least pass through critical depth. If decreases in water surface elevation are shown, convergence within 0.5' are acceptable. If not, the analysis should be extended upstream until convergence or critical depth is reached.

**Cross Section Plots.** The report should include plots of the cross sections, looking downstream. Cross section plots should be clear and have proposed conditions superimposed onto the existing conditions. Computer generated plots are often of a scale which does not clearly differentiate between existing and proposed conditions. In these situations, the applicant should provide drafted plots of the project area large enough so that existing versus proposed conditions are clearly depicted. The scale of the plots should be clearly denoted. A plan sheet showing cross section locations is required.

**Tables.** Table fields should be clearly labeled. A separate table should be shown for each discharge. Each cross section that is used in the model should be listed together with the published FEMA water surface elevation, existing and proposed conditions. FEMA lettered sections should be labeled. Include the differences between the FEMA and the existing model, and the difference between the existing and the proposed model.

### ***Summary***

#### **Include in the hydraulic package:**

- Natural, existing, and proposed models based on the appropriate discharge.
- Computer diskette or CD (preferred) with input.
- Adequate narrative.
- Hydraulic Data Sheets.
- Profiles – one page per discharge.
- Cross sections.
- Tables – one table per discharge.
- Plans including erosion and sediment controls and water handling

## **Section 5. Other Important Considerations**

**Fish Passage.** Projects must be designed to accommodate fish passage and maintain fish habitat where needed. If a culvert is proposed instead of a bridge, some methodologies used to provide fish passage are: sinking a box culvert bottom roughly one foot to allow accumulation of natural sediment in the box, providing a low flow channel, or using an inverted “U” type culvert in order to leave a natural bottom. Whenever a box culvert is proposed as a new river crossing or as a replacement for an existing bridge, it is advisable to contact the DEP Fisheries Division prior to completing plans for submittal to DEP. The main office telephone number for the DEP Fisheries Division is 860-424-3474.

**Spanning the Floodway.** When an existing bridge spans the floodway, with its abutments at or outside the floodway limits, a proposal to replace the bridge in kind or with a greater span will not require a floodway evaluation provided the low chord of the existing and proposed bridge is higher than the floodway elevation. This information must be clearly shown on plans and elevations. In the design of a new crossing, it is highly recommended that no part of the structure be within the floodway. This will eliminate the need for a floodway assessment but does not negate the need for obtaining an environmental permit(s) or approval of a flood management certification.

**Overtopping of Local Bridges.** Under certain limited conditions defined by regulation, local bridges may be allowed to overtop by floodwaters if site constraints so warrant. In this case, the application must state how the bridge will be closed to traffic in the case of a flood, what detour routes are available, and that the bridge will be posted as being prone to flooding.

**Flood Storage.** When a hydraulically inadequate bridge or culvert is proposed to be replaced and a significant drop in backwater at the structure is expected, the applicant must investigate whether the subsequent loss of upstream flood storage will have an adverse downstream impact. Information provided to DEP to show the downstream impact should include the volume of storage upstream of the bridge lost in acre-feet. If the volume of storage lost is significant, more detailed flood storage routing may be required. Measures such as replacing the bridge or culvert in kind may have to be taken to avoid an adverse downstream impact.

**Metric vs. English Units.** Projects are sometimes designed using metric units, in compliance with past federal mandates. An hydraulic analysis which is completed in metric units may be submitted with an application; however, the summary must contain tables in both English and metric.

**Tailwater Control.** Occasionally a bridge or culvert will be inundated by backwater from a downstream river or from Long Island Sound. In these cases the hydraulic analysis should generally be conducted using the design inland storm together with a ten-year tailwater elevation, unless it can be demonstrated that use of a different tailwater elevation would be appropriate. DEP should be contacted for concurrence prior to submission of the report.

**Channel Restoration.** Channel restoration plans must be provided for all open channel work. The plan will help restore and/or create an aquatic habitat suitable for fisheries, if applicable, as well as maintain or improve water quality, recreation, aesthetics and flow capacity. The channel restoration plan should include, as appropriate: avoidance of barriers to fish movement; formation of pools and riffles; provisions for areas of sheltered flow with use of deflectors, boulders, or low check dams; preservation of stream bank vegetation and establishment of new vegetation; use of clean natural bed materials of a suitable size; scheduling of work to minimize conflicts with spawning, stocking, and fishing season; and removal of excess debris. The plan must be designed to avoid adverse hydraulic impacts from obstructions placed in the stream. Consultation with the DEP Fisheries Division is recommended.

**Temporary Hydraulic Facilities.** Temporary hydraulic facilities include, among other things, temporary bridges, by-pass channels, haul roads or channel constrictions such as cofferdams. The Connecticut Department of Transportation Drainage Manual 2000 (<http://www.CT.gov>), Chapter 6, Section 15, and Appendix 6.F describes the methodology for determining the temporary design discharge for such facilities. Such facilities must be capable of conveying the temporary design discharge for the temporary facility without endangering life or property (including the structure under construction). The temporary hydraulic facilities should not cause roadways to be overtopped or aggravate existing flooding conditions during the temporary design discharge. In the case where such facilities are utilized, the hydraulic design based on the DOT drainage manual must be provided.

**Hydraulic Data Sheets.** Hydraulic data sheets should accompany every hydraulic report involving a bridge. Data sheets may be found in the DOT Drainage Manual, Chapter 9, Appendix A.

**Plans.** Plans should be provided that are in conformance with the requirements listed in the application instructions DEP-IWRD-INST-100. Plans must include erosion and sediment controls as well as water handling and sequence of construction information.

**Preapplication Meetings.** In cases where a project is hydraulically complex or problems with hydraulic modeling are foreseen, a preapplication meeting with IWRD engineering staff is highly recommended.

**Copies.** Only one copy of a hydraulic analysis should be submitted with an application, regardless of how many total copies of the application are required. This does not include plans which must be submitted in the appropriate number.

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